CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-187

CLEGHORN AND RELATED FAULTS, SAN BERNARDINO COUNTY

by

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INTRODUCTION

Potentially active faults in southwestern San Bernardino County that are evaluated in this Fault Evaluation Report (FER) include strands of the Cleghorn, Silverwood Lake, and Grass Valley faults, and the southern Tunnel Ridge lineament (figure 1). The western San Bernardino Mountains study area is located in parts of the Cajon, Silverwood Lake, and Lake Arrowhead 7 1/2-minute quadrangles (figure 1). These faults are evaluated as part of a statewide effort to evaluate faults for recency of activity. Those faults determined to be sufficiently active and well-defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act of 1972 (Hart, 1985).

Traces of the San Andreas and northern San Jacinto fault zones, and related faults were zoned for special studies in 1974 in the Cajon quadrangle (figure 2a). These two fault zones will not be evaluated in this FER. Re-evaluation of these faults should be accomplished if time and scheduling permit because zoning for special studies in 1974 was based on the criterion of Quaternary-active faulting. Some of these fault segments in the Cajon quadrangle may not meet the current criteria for zoning.

SUMMARY OF AVAILABLE DATA

The western San Bernardino Mountains study area is located in the Transverse Ranges geomorphic province and is dominated by compressional tectonics of the San Andreas fault system. Faults within the study area are generally characterized by northwest-trending right-lateral strike-slip faults and east- to northeast-trending left-lateral strike-slip faults.

Topography in the study area is rugged, with elevations ranging from 915m to 1520m. Almost all slopes in the study area are covered by dense brush, which renders access and observation of subtle geomorphic features very difficult (photo 1). Development in the study area is generally low. The central and east-central segments of the Cleghorn and Silverwood Lake faults are located in California State Park Service land and the majority of the study area is located in the San Bernardino National Forest.

Rock types in the study area include pre-Mesozoic metamorphic rocks, Mesozoic plutonic rocks, Miocene and Pliocene sedimentary rocks (including Miocene Punchbowl and Miocene-Pliocene Crowder Formations), and Quaternary alluvium (Dibblee, 1965, 1974; Woodburne and Golz, 1972; Weldon and others, 1981; Meisling, 1984). Significant Quaternary alluvial deposits include five levels of fluvial terrace deposits in the Cajon Pass area (ages range from late Holocene to approximately 500,000 ybp) (Weldon and others, 1981; Meisling, 1984; Weldon and Sieh, 1985; McFadden and Weldon, 1987), and two terrace levels in the Cleghorn Canyon-Miller Canyon area (Weldon and others, 1981; Meisling, 1984).

CLEGHORN FAULT ZONE

The Cleghorn fault zone is a 24-km-long, generally east-trending zone of left-lateral strike-slip faults (figures 1, 2a, 2b). At its western end, the Cleghorn fault changes to a northwest trend and is concealed by Holocene alluvium in Cajon Canyon (figure 2a). The easternmost segment of the Cleghorn fault turns to the northeast and apparently merges with the northeast-trending Tunnel Ridge lineament (figure 2b). The Cleghorn fault has been mapped by Dibblee (1965), at a scale of 1:62,500, and in detail by Weldon and others (1981) and Meisling (1984). Only Weldon and others (1981) and Meisling (1984) are evaluated in this FER (figures 2a, 2b). The ancestral Cleghorn fault (Cedar Springs fault system) is thought to have been a reverse fault with down-to-the-south displacement (Meisling, 1984). Lateral displacement along the modern Cleghorn fault zone probably commenced in earliest Pleistocene time according to Weldon and others (1981) and Meisling (1984).

Cumulative left-lateral displacement of 3 1/2 to 4 km has occurred along the Cleghorn fault. The magnitude and sense of displacement are indicated by: (1) left-lateral displacement of 3 to 4 km of fold axes in the Miocene-Pliocene Crowder Formation; (2) 4 km left-lateral displacement of a steeply dipping basement/Miocene Punchbowl Formation contact; and (3) left-lateral offset of 3 1/2 to 4 km of members of the Cedar Springs fault system (Squaw Peak/Powell Canyon faults and Notch/Seeley Creek faults) (Meisling, 1984) (figure 3).

Late Quaternary displacement of 1.1 km along the Cleghorn fault has been reported by Meisling (1984). In Cleghorn Canyon, a terrace deposit (Qte) containing angular quartzite clasts was reported to be offset 1.1 km across the Cleghorn fault (Weldon and others, 1981; Meisling and Weldon, 1982; Meisling, 1984) (locality 1, figure 2a). The Qte terraces are estimated to be about 400,000 to 500,000 yr. old, based on known slip-rates along the San Andreas fault (Meisling, 1984; Weldon and Sieh, 1985; McFadden and Weldon, 1987). Weldon and others (1981) and Meisling (1984) also proposed that correlation of equivalent-aged alluvial fan/terrace deposits offset by the Cleghorn fault in Miller Canyon indicated about 1 km of left-lateral offset (figures 2b, 4). A late Quaternary slip-rate of 2.75 mm/yr. was calculated using these data.

Late Pleistocene terraces are mapped as offset along the Cleghorn fault by Weldon and others (1981) and Meisling (1984) (figures 2a, 2b). In the Cajon Pass area, Qtc terraces thought to be about 60ka are offset (Weldon and others, 1981) (figure 2a). Locally, a Qta terrace is mapped as offset (locality 2, figure 2a). Qtl terraces in Cleghorn Canyon, which are correlated with Qtc and Qtd terraces in Cajon Canyon, are locally offset along the Cleghorn fault (figure 2b).

Geomorphic evidence of latest Pleistocene and Holocene offset along the Cleghorn fault was reported by Weldon and others (1981), Meisling and Weldon (1982), and Meisling (1984). An approximately 1-km-long scarp in bedrock is evidence of Holocene displacement according to these workers (locality 3, figure 2a). Meisling (1984, p. 272) reported that the crests of small ridges are left-laterally offset, creating backfacing scarps on the east side of the ridges. A trough at the base of the scarp is not filled with colluvium, indicating very recent movement (Weldon and others, 1981; Meisling, 1984). Two left-laterally offset drainages are also cited as geomorphic evidence for recent (Holocene) offset along the Cleghorn fault (locality 4, figure 2b). These two small drainages, cut into 60,000 yr. old Qtl terrace deposits, are offset about 200 meters according to Weldon and others (1981) and Meisling

(1984). These data allow a late Pleistocene slip-rate of 3.3 mm/yr. to be calculated for the Cleghorn fault.

Meisling (1984) classified the Cleghorn fault as active, based on the geomorphic features delineating the fault and the offset late Pleistocene terrace deposits.

SILVERWOOD LAKE FAULT ZONE

The Silverwood Lake fault zone is a northeast-trending fault zone that consists of the West Silverwood Lake fault and the East Silverwood Lake fault (figure 2b). The Silverwood Lake fault zone, which splays off of the Cleghorn fault zone, is considered by Weldon and others (1981) and Meisling (1984) to be a left-lateral fault with a minor component of down-to-the-southeast vertical displacement. Cumulative left-lateral displacement along the Silverwood Lake fault zone is not known, but Weldon and others (1981) suggest that approximately 1/2 km of left-lateral offset may have occurred, based on the apparent offset of an east-trending reverse fault.

Evidence of late Quaternary activity along the Silverwood Lake fault zone is indicated by offset terrace deposits mapped by Weldon and others (1981) and Meisling (1984) (locality 5, figure 2b). Evidence of late Pleistocene to Holocene displacement along the East Silverwood Lake fault was reported by California Department of Water Resources during exploration for the Cedar Springs Dam (CDWR, 1968) (locality 6, figure 2b). Trench T-21 exposed granitic bedrock on the northwest faulted against Harold Formation (Crowder Fm?) on the southeast (figure 5). The base of the overlying alluvium is offset about 1 1/2 meters in an apparent vertical sense, southeast-side-up. Clasts are vertically oriented along a root zone in the alluvium that lies along the upward projection of the fault plane in bedrock. It was concluded by DWR that the East Silverwood Lake fault (their fault No. 2) was potentially active and modified the design of the Cedar Springs Dam accordingly.

GRASS VALLEY FAULT ZONE

The Grass Valley fault zone is a west to west-northwest-trending left-lateral strike-slip fault (Meisling, 1984) (figure 2b). The Grass Valley fault zone is in granitic bedrock, so Meisling (1984) postulated that up to 1 km of left-lateral displacement has occurred along the fault based on geomorphology. Vertical displacement along the Grass Valley fault zone is not more than several tens of meters, based on the separation of the base of the Crowder Formation and the late Miocene erosion surface (Meisling, 1984). Based on the youthfulness of the geomorphic expression of the Grass Valley fault zone, Meisling estimated that movement along the fault zone was post middle Pleistocene.

TUNNEL RIDGE LINEAMENT

The Tunnel Ridge lineament is a significant northeast-trending fault in bedrock mapped by Dibblee (1974) and Meisling (1984) (Dibblee not plotted) (figure 2b). The style and magnitude of offset along the Tunnel Ridge lineament is not known. Meisling pointed out that significant vertical displacement along the Tunnel Ridge lineament has not occurred because of the relative continuity of the late Miocene erosion surface across the fault. Left-lateral strike-slip displacement probably characterizes the fault at its southern end where it complexly joins the Cleghorn fault (Meisling, 1984) (figure 2b). Geomorphic expression of the Tunnel Ridge lineament is limited mainly to broad, linear valleys developed on the late Miocene erosion surface

(Meisling, 1984). Although Meisling did not evaluate the Tunnel Ridge lineament in detail, he assumed that the fault must have had displacement since middle Pleistocene time, based mainly on the fault's association with the Cleghorn fault to the southwest and the Sky High Ranch fault (via the Arrastre Canyon graben) to the northeast (see Bryant, 1986) (figure 1).

INTERPRETATION OF AERIAL PHOTOGRAPHS AND FIELD OBSERVATIONS

Aerial photographic interpretation by this writer of faults in the western San Bernardino Mountains study area was accomplished using U.S Department of Agriculture (AXL, 1953, scale 1:20,000), U.S. Bureau of Land Management (CAHD-77, 1978, scale 1:30,000), and U.S. Army Corps of Engineers (MR, 1939, scale 1:18,000) air photos.

Approximately 4 1/2 days were spent in the study area in mid-October 1986 by this writer. Selected fault segments were verified and subtle features not observable on the aerial photographs were mapped in the field. Results of aerial photographic interpretation and field observations by this writer are summarized on figures 2a and 2b.

CLEGHORN FAULT ZONE

The Cleghorn fault zone mapped by Weldon and others (1981) and Meisling (1984) was only locally verified by this writer, based on air photo interpretation and limited field checking (figures 2a, 2b). The Cleghorn fault is generally poorly defined and lacks geomorphic features characteristic of latest Pleistocene to Holocene left-lateral strike-slip displacement (figures 2a, 2b). Segments of the Cleghorn fault zone that are moderately well-defined include the eastern part of Cleghorn Canyon and the central part of Miller Canyon (figure 2b; photo 1). Geomorphic features, such as benches, saddles, a sidehill bench, both left-and right-laterally deflected drainages, and vegetation contrasts, characterize these fault segments (localities 7 and 8, figure 2b). The geomorphic features are permissive of recent faulting, but systematically deflected drainages (left-lateral), shutter ridges, troughs, ponded alluvium, and offset ridges were not observed. The surfaces of the Qt2 terraces mapped by Weldon and others (1981) and Meisling (1984) in the Miller Canyon area are poorly defined and could only locally be identified by the writer, based mainly on air photo interpretation. The correlation of specific Qt2 terraces across the Cleghorn fault (figures 2b, 4) seems to be quite tenuous.

The backfacing scarp reported by Weldon and others (1981) and Meisling (1984) at locality 3 is clearly Holocene in age (figure 2a). However, this writer could only verify an approximately 460-meter-long, slightly sinuous backfacing scarp in bedrock. The left-laterally offset ridges reported by Meisling (1984) along this feature were not verified; the backfacing scarp is located on both the east and west sides of the ridge crests, based on interpretation of U.S.D.A. (1953) and U.S.A.C.E. (1939) air photos. The sinuousity of the scarp indicates a north-dipping ~~slope~~ plane. No geomorphic evidence of recent faulting was observed to the west of this backfacing scarp. A linear ridge is located to the east of the scarp, but could be erosional. The backfacing scarp is probably not tectonic in origin, but may be a lateral spread feature. Weldon and others (1981) and Meisling (1984) mapped a small landslide just upslope of this backfacing scarp; the small slide may be a part of a larger, older landslide (locality 3, figure 2a). The backfacing scarp was not observed beyond the inferred boundaries of the older landslide.

slip

The two left-laterally deflected drainges reported by Weldon and others (1981) and Meisling (1984) are not sharply deflected and associated geomorphic evidence of Holocene left-lateral offset was not observed by this writer (locality 4, figure 2b). The late Pleistocene Qtl terrace surface west of the deflected drainages does not seem to be offset, based on air photo interpretation and field checking by this writer (figure 2b).

Direct evidence of Holocene displacement along the Cleghorn fault was not observed by this writer. The offset Holocene Qta terrace mapped by Weldon and others (1981) and Meisling (1984) was not verified by this writer (locality 2, figure 2a). The Qtl terraces mapped by Weldon and others (1981) and Meisling (1984) generally have Bt soil horizon development, precluding a Holocene age for these surfaces. I agree with the 60 ka age assigned by Meisling (1984). Evidence of late Pleistocene displacement along the Cleghorn fault was observed at locality 9 (figure 2b). The base of the Qtl terrace deposit is offset, but the fault cannot be traced up into the upper terrace deposits and the Bt soil horizon is not offset (figure 2b; photo 2).

SILVERWOOD LAKE FAULT ZONE

The West Silverwood Lake fault was generally verified as mapped by Weldon and others (1981) and Meisling (1984) (figure 2b). The northeast-trending fault is delineated by geomorphic features in bedrock, such as escarpments, saddles, and vegetation contrasts (figure 2b). However, geomorphic evidence of latest Pleistocene to Holocene left-lateral displacement, (systematic deflection of drainages, shutter ridges, offset ridges) was not observed by this writer, based on air photo interpretation.

The East Silverwood Lake fault is generally poorly defined and is not characterized by geomorphic evidence of recent left-lateral strike-slip faulting (figure 2b). The fault is located in a broad, generally linear valley, but much of the fault is now concealed by Silverwood Lake. Interpretation of 1953 and 1939 air photos that pre-date construction of the Cedar Springs dam indicate that the East Silverwood Lake fault is delineated by a subtle vegetation contrast in a late Quaternary terrace deposit in the vicinity of CDWR trench T-21 (locality 6, figure 2b). Well-defined tonal lineaments in Holocene alluvium, deflected drainages, or scarps in alluvium were not observed by this writer along the East Silverwood Lake fault.

GRASS VALLEY FAULT ZONE

The Grass Valley fault zone mapped by Weldon and others (1981) and Meisling (1984) was generally verified by this writer, based on air photo interpretation and limited field checking (figure 2b) (also see Bryant, 1986). The westernmost segment of the fault is moderately well-defined and is delineated by linear ridges, bedrock escarpments, linear drainages, and vegetation contrasts in bedrock (figure 2b). A sidehill bench (locality 10, figure 2b) is suggestive of recent faulting, but associated geomorphic features, such as systematically offset drainages, were not observed. The eastern Grass Valley fault zone is not well-defined and is delineated by broad linear valleys characteristic of erosion along a fault rather than recent displacement.

TUNNEL RIDGE LINEAMENT

The Tunnel Ridge lineament is a moderately defined, northeast-trending fault in bedrock (figure 2b). The fault is delineated by geomorphic features such as linear drainages, deflected drainages (both right and left-lateral), and aligned saddles in bedrock (figure 2b) (also see Bryant, 1986). Geomorphic evidence of recent, systematic strike-slip displacement was not observed by this writer along the Tunnel Ridge lineament, based on brief air photo interpretation.

SEISMICITY

Seismicity in the western San Bernardino Mountains study area is depicted in figure 6. A and B quality epicenter locations by California Institute of Technology are for the period 1932 to 1985 (CIT, 1985).

The Cleghorn fault is not delineated by a well-defined zone of seismicity (figure 6). The western part of the Cleghorn fault is seismically quiescent, but clusters of epicenters occur near the fault zone in the eastern Cleghorn Canyon area, Miller Canyon area, and the area between the Cleghorn fault zone and the Grass Valley fault zone (figure 6).

CONCLUSIONS

CLEGHORN FAULT ZONE

The Cleghorn fault zone is a 24-km-long left-lateral strike-slip fault (Weldon and others, 1981; Meisling and Weldon, 1982; Meisling, 1984) (figures 2a, 2b). The Cleghorn fault mapped by Weldon and others (1981) and Meisling (1984) generally is poorly defined and is not characterized by geomorphic evidence of latest Pleistocene to Holocene left-lateral displacement, such as systematically offset drainages. Late Pleistocene displacement along the fault was verified by this writer at locality 9 (figure 2b; photo 2). However, the geomorphic evidence of latest Pleistocene to Holocene displacement cited by Weldon and others (1981) and Meisling (1984) was not verified by this writer, based on air photo interpretation and limited field checking. The backfacing scarp at locality 3 (figure 2a) is only about 460 meters long and is anomalously youthful and well-defined in comparison with the rest of the Cleghorn fault. This feature is within the inferred boundaries of an old landslide, is probably a lateral spread feature, and is not tectonic in origin (figure 2a). The two left-laterally deflected drainages reported by Weldon and others (1981) and Meisling at locality 4 are not sharply deflected and are not associated with additional geomorphic features indicating recent faulting (figure 2b).

Late Quaternary slip-rate calculations for the Cleghorn fault are rated as having significant to major uncertainties, according to Meisling (1984, p. 278). The calculated slip-rate of 2.75 to 3.3 mm/yr. for the Cleghorn fault seems to be much too high. This conclusion is based on the overall lack of geomorphic evidence of recent left-lateral strike-slip displacement along the Cleghorn fault, the uncertainties this writer has about the proposed correlation of Qt2 terraces across the Cleghorn fault (figure 4), and the unconvincing drainage deflections at locality 9 (figure 2b).

SILVERWOOD LAKE FAULT ZONE

The Silverwood Lake fault zone is a northeast-trending left-lateral fault zone consisting of the West and East Silverwood Lake faults (Weldon and others, 1981; Meisling, 1984) (figure 2b). CDWR (1968) exposed evidence of latest Pleistocene to Holocene displacement along the East Silverwood Lake fault (locality 6, figure 2b, figure 5). However, the East Silverwood Lake fault zone is generally poorly defined and much of the fault is now concealed by Silverwood Lake. The West Silverwood Lake fault is marginally better defined than the East Silverwood Lake fault, but neither fault is delineated by geomorphic evidence of recent left-lateral strike-slip faulting (figure 2b). The age of the offset alluvium at the CDWR trench is not precisely known. Weldon and others (1981) indicate that it is late Pleistocene while Stankov (1982) indicates that the alluvium is Holocene. The geomorphic surface may be late Pleistocene, based on air photo interpretation. Thus, if the Silverwood Lake fault zone is active, the slip-rate must be quite low.

GRASS VALLEY FAULT ZONE

The Grass Valley fault zone is a west to west-northwest-trending left-lateral strike-slip fault (Meisling, 1984) (figure 2b). Meisling estimated that movement along the Grass Valley fault zone was post-middle Pleistocene. The fault is locally moderately well-defined in granitic bedrock, but it lacks geomorphic features indicating recent strike-slip faulting (figure 2b).

TUNNEL RIDGE LINEAMENT

The Tunnel Ridge lineament is a moderately defined, northeast-trending fault mapped by Dibblee (1974) and Meisling (1984) (figure 2b). Meisling stated that the sense of displacement is not known, but it is probably left-lateral strike-slip in the study area. Geomorphic evidence of recent strike-slip faulting along the Tunnel Ridge lineament was not observed by this writer, based on air photo interpretation.

RECOMMENDATIONS

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well-defined" (Hart, 1985).

CLEGHORN FAULT ZONE

Do not zone for special studies. Evidence of Holocene activity has not been demonstrated and this fault zone generally is poorly defined.

SILVERWOOD LAKE FAULT ZONE

Do not zone for special studies. This fault zone is poorly defined and probably has a very low rate of activity.

GRASS VALLEY FAULT ZONE

Do not zone for special studies. The fault zone is neither sufficiently active nor well-defined in detail.

TUNNEL RIDGE LINEAMENT

Do not zone for special studies. This fault zone is not sufficiently active and generally is not well-defined in detail.

Reviewed; recommendations approved, Earl W. Hart 5/4/87

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Photo 1 (to FER-187). View west of the Cleghorn fault along the western part of locality 8 (figure 2b). The Cleghorn fault is delineated by benches and vegetation lineaments, but geomorphic evidence of latest Pleistocene to Holocene left-lateral displacement was not observed.

Photo 2 (to FER-187). East-trending segment of the Cleghorn fault offsets Miocene Crowder Formation and deforms the base of a Qtl terrace deposit about 15 cm (up-to-south)(view to east). The fault (arrows) trends N80°E 75°S; vertical striations on fault plane indicate a predominantly vertical sense of displacement. The fault does not extend into the terrace deposit and the Bt soil horizon is not offset.

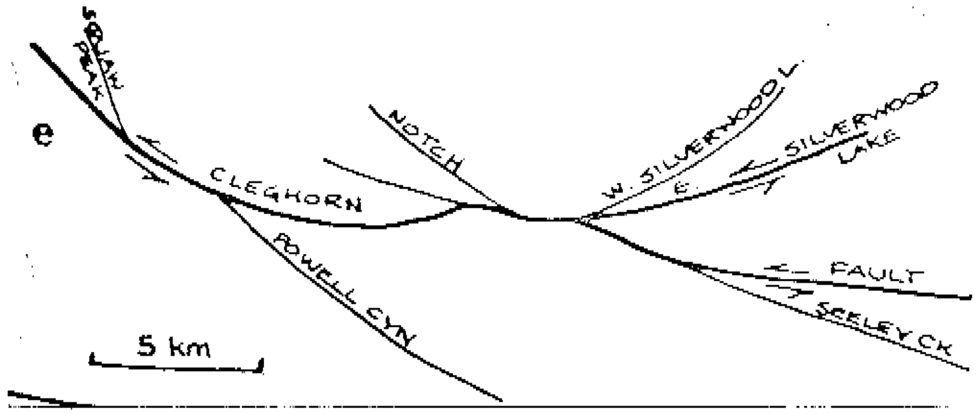

Figure 3 (to FER-187). Configuration of Cleghorn fault zone, showing left-laterally offset members of the Cedar Springs fault system. Weldon and others (1981) and Meisling (1984) postulated that 3 1/2 to 4 km of left-lateral displacement has occurred along the Cleghorn fault, based on the suggested offset of the Squaw Peak/Powell Canyon and Notch/Seeley Creek faults (from Meisling, 1984).

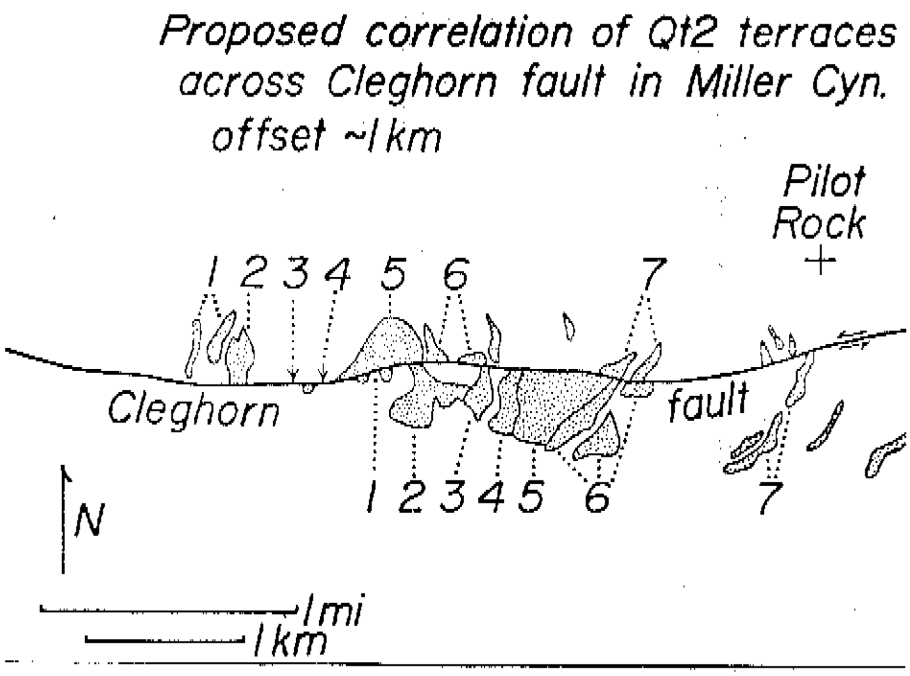

Figure 4 (to FER-187). Proposed correlation of Qt2 terraces in Miller Canyon (see figure 2b). A late Quaternary slip-rate of 2.75mm/yr was calculated by Meisling (1984) for the Cleghorn fault, based on this proposed correlation and an estimated age of 400ka for the terrace surfaces (from Meisling and Weldon, 1982).

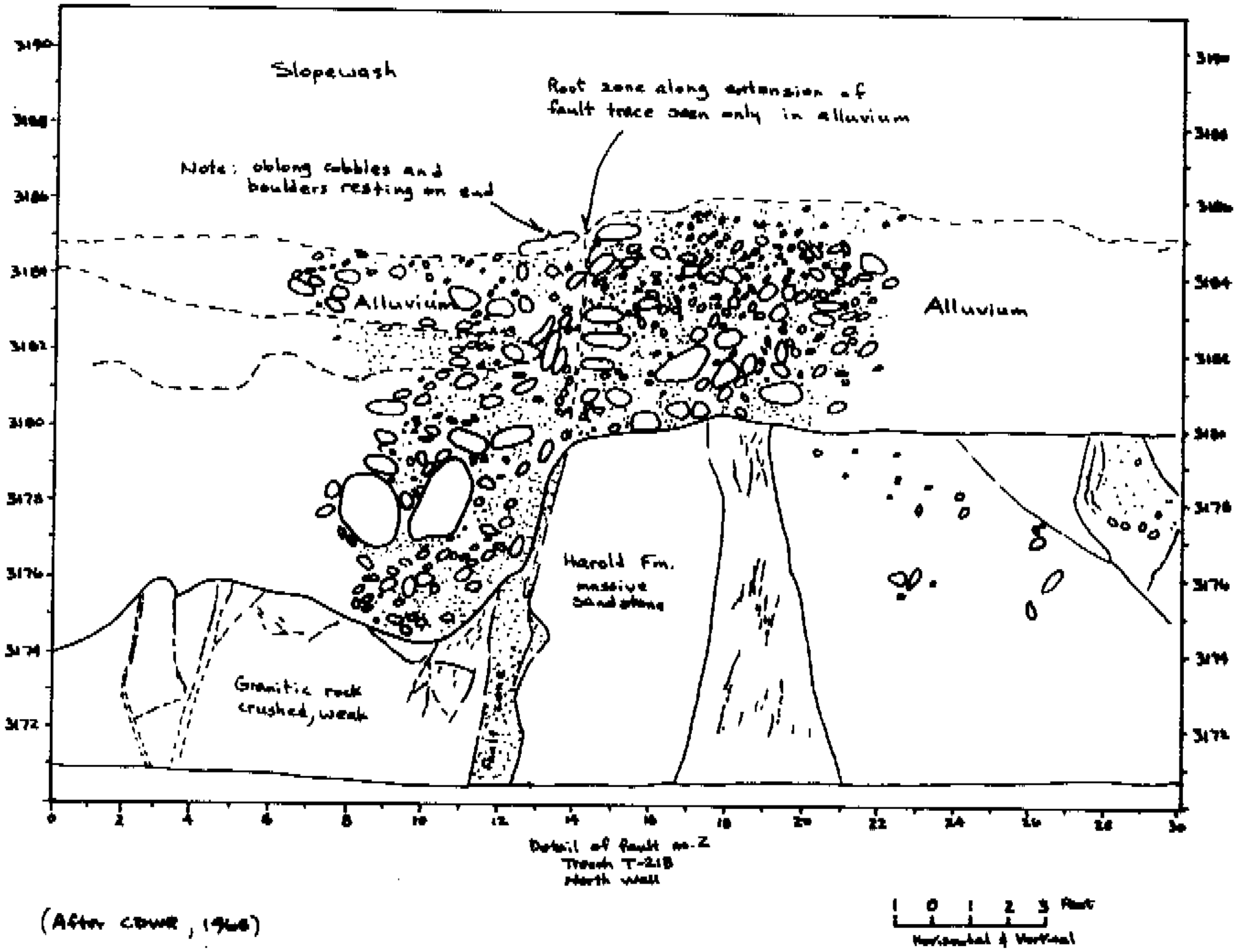

Figure 5 (to FER-187). Trench log T-21 (northeast face) across trace of the East Silverwood Lake fault. Miocene Harold Formation (Crowder Formation of Weldon and others, 1981) is offset against granitic bedrock. The base of the overlying alluvium is offset about 5 feet (1.5 m), up on the southeast. The fault plane in the alluvium is delineated by a root zone and pebbles rotated into the plane of the fault. The age of the alluvium is not precisely known: Weldon and others (1981) estimated it to be late Pleistocene, while Stankov (1982) estimated the age to be Holocene. See figure 2b for location of trench. Log from C.D.W.R.(1968).

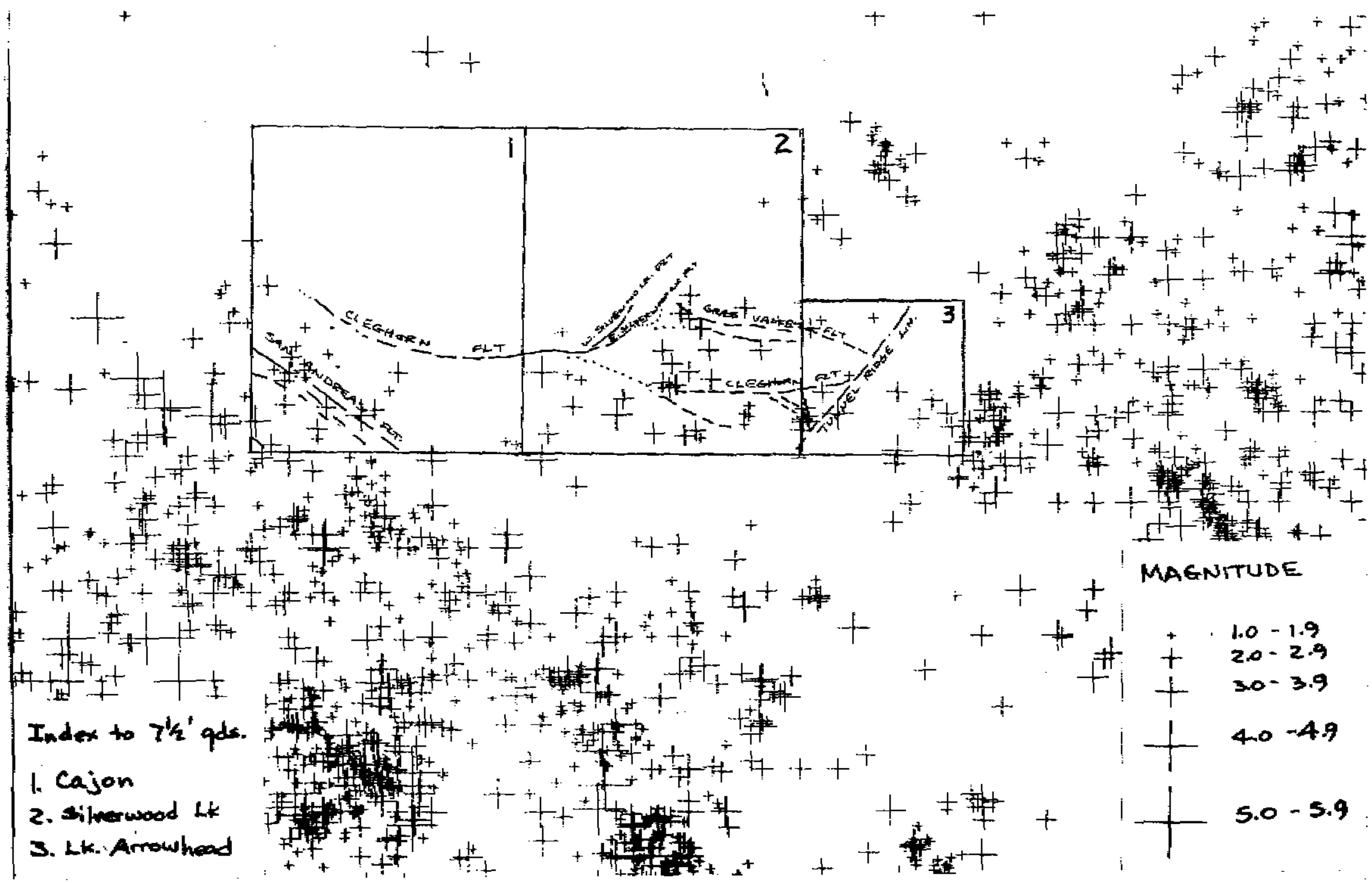

Figure 6 (to FER-187). Seismicity (A and B quality) in the western San Bernardino Mountains study area for the period 1932 to mid-1985, based on locations from California Institute of Technology (1985). Faults are from Rogers (1967) and Bortugno and Spittler (1986), scale 1:250,000.